Tab 4. Petroleum Hydrocarbons in Fish and Sediments of NPRA: Teshekpuk Lake Area and the Colville. Ikpikpuk, Meade, and Kuk Rivers. June 2012

Petroleum Hydrocarbons in Fish and Sediments of NPR-A: Teshekpuk Lake Area and Colville, Ikpikpuk, Meade and Kuk Rivers

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Introduction:

Research has recently focused on the environmental levels and potential effects of toxic substances on Native communities within subsistence cultures of the Arctic. For example, this has been a major component of the Arctic Monitoring and Assessment Program (AMAP 1998). Responses to contaminants range from direct hazards to health and survival to more subtle changes in lifestyle patterns (AMAP 1997; Jensen 1998).

As summarized recently by Reynolds et al. (2006), multiple benefits derive from a subsistence lifestyle for Alaska Natives, including include facilitating self-definition and self-determination, maintaining communities as close-knit entities, providing economic gain, and promoting good nutrition and health (Egeland et al., 1998; Hild, 2002; Arnold and Middaugh, 2004; Verbrugge and Middaugh, 2004). In some cases, perceptions regarding the possible presence and levels of anthropogenic contaminants in subsistence harvested food have caused a reduction in consumption of traditional foods, followed by documented health effects (Egeland et al., 1998; Arnold and Middaugh, 2004; Verbrugge and Middaugh, 2004). Whereas traditional diets high in marine mammals and fish have historically been suggested to reduce the likelihood of cardiovascular disease (heart attacks and strokes), diabetes, and other adverse health conditions in Alaska Natives, recent changes in dietary preferences have been associated with increased prevalence of these diseases in some Native communities (e.g., Nobmann et al., 1992; Egeland et al., 1998; Hild, 2002; McLaughlin et al., 2004). Verbrugge and Middaugh (2004; page 2) concluded that "the potential risks associated with POP [persistent organic pollutant] exposure through subsistence food consumption are smaller than the risks associated with a decreased us of traditional foods…" The same may be true for other classes of chemical contaminants as well.

Among the least well-examined classes of contaminants along the North Slope of Alaska are the petroleum hydrocarbons (HCs). More specifically, the polycyclic aromatic hydrocarbons (PAHs) represent the most toxic fraction of oil, and sixteen PAHs are included on lists of priority chemical contaminants by the World Health Organization and the U.S. Environmental Protection Agency (EPA). These toxicants may enter local environments in a variety of ways, including natural seeps, discharges from tanks and vessels, loss associated with escalating oil and gas development, and catastrophic spills.

Although, as noted, PAHs have not been well studied in the environment or living organisms of Alaska's North Slope, recent, current, and proposed future oil and gas activities make it vitally important that research and monitoring programs be initiated immediately to create baselines and provide empirical information needed for possible mitigation. Of particular concern are areas within the National Petroleum Reserve-Alaska (NPR-A).

The NPR-A represents the largest single block of publicly owned land in the United States: 23.5 million acres. The area has recognized value for a number of disparate reasons, including as a site of oil and gas exploration and development, a location with diverse and abundant wildlife, and a resource for Alaska Natives (Inupiat people) who have hunted, fished, and lived there for millennia (http://www.audubonalaska.org/m3item5.html). The NPR-A was established originally as the Naval Petroleum Reserve Number 4 by President Harding in 1923, but it was not until 1980 that Congress authorized leasing and development activities for oil. Such activities now fall under the jurisdiction of the Department of the Interior and must be done in ways that ensure protection of "surface values" including wildlife populations. The Minerals Management Service has estimated that the northeastern corner of the NPR-A *alone* contains more than 3 billion barrels of technically recoverable oil and almost 10 trillion cubic feet of gas (http://www.agiweb.org/gap/legis106/npra.html), a huge resource that will provide a challenge in terms of an effective balance between exploration/development and environmental conservation.

Thus, most oil and gas-related activities in the NPR-A are of recent origin. Until recently oil and gas leases had been let for a little more than 5% of the NPR-A (1.3 million acres), but in 2004, 8.8 million acres in the northwestern NPR-A Planning Area were made available for oil and gas leasing (http://www.blm.gov/ak/nepa_arctic/ea06-003.pdf). Of particular concern is the fact that the current no-lease zone to the north and east of Teshekpuk Lake area is being reconsidered for future activities (http://www.audubonalaska.org/m3item5.html).

In the face of expanding oil and gas activities, concern continues to exist for several reasons including effects on the internationally important wildlife populations for which the area is well known and the safety and well-being of the Alaska Native communities who continue to use the NPR-A to hunt and fish for food important to their subsistence lifestyle (Huntington et al. 1998). Some areas of the NPR-A have been the sites of oil and gas development for some time (70 wells to date), and expansion of exploration and development to the west across the Colville River (e.g., Umiat site) has heightened the perceived risk to and concern of local residents regarding chronic and acute PAH pollution.

To date, most concern has centered around catastrophic or acute events such as oil spills. The direct effects of acute oil pollution could affect socio-economic and cultural activities, as well as include a variety of health effects (http://oils.gpa.unep.org/facts/economy-health.htm). However, in wildlife (e.g., marine mammals) the health effects of chronic oil contamination may also be significant, and could include a range of conditions, such as carcinogenesis and mutagenesis; disruption of immune and endocrine system function; dermal irritation; and other ailments. In light of such possibilities, subsistence communities of the North Slope are concerned that PAHs could enter humans through consumption of a variety of species that constitute important parts of the Inupiat diet. In response to these concerns, coupled with the importance for subsistence and the vulnerability to contamination of the fish stocks of the NPR-A, this project had several objectives, as follows:

- establish baseline values of PAHs in sediments collected from locations in Teshekpuk Lake area and the Colville and Ikpikpuk, Meade and Kuk rivers (**Figures 1 and 8**);
- examine PAH levels in the muscle and liver of seven fish species; broad whitefish, (*Coregonus nasus)* burbot (*Lota lota)* lake trout (*Salvelinus namaycush*), sculpin (*Gymnocanthus pistilliger*) round whitefish (*Prosopium cylindraceum*), arctic grayling (*Thymallus arcticus*) and smelt (*Osmerus mordax*), commonly consumed by local communities;
- assess the origin or oil pollution through "fingerprinting" to clarify whether PAHs are primarily from fresh or combusted oil sources; and
- provide our results (presentations, maps, reports) to the scientific community and to local residents.

Although we felt that it is unlikely that current concentrations of petroleum hydrocarbons would be high in the locations we sampled because anthropogenic inputs (spills and runoff) have been minimal to date, it is vital to ascertain contaminant levels and to establish baselines against which to assess effects of future oil inputs. Only with empirical data in hand can informed decisions regarding human health and nutritional risks be made.

Methods:

PAH analyses-Sediments and tissue samples from selected fish were collected in the field during 2004, 2005, 2008 and 2010. Sample collection GPS station locations for all samples locations can be found in **Table 1**. Tissue samples from net-caught fish included muscle and liver that were sub-sampled in the field using fresh solvent-cleaned, stainless steel scalpels for each sample. Each tissue was stored in a separate pre-cleaned glass jar with a Teflon lined lid and frozen. Sediments were collected using a sediment grab and stored as above. Samples were shipped frozen to Mote Marine Laboratory and stored frozen until analysis.

An aliquot from each sample was removed for moisture content analysis. Approximately 30 g each of sediments, 5 g of liver and 10 g of muscle tissue were weighed out to the nearest 0.1 g and appropriate polycyclic aromatic hydrocarbon (PAH) internal standards were then added. All samples were extracted using a Dionex ASE 300, extraction system following modified EPA methods (EPA 1998).

The extracts were then evaporated to near dryness, and re-dissolved in 1 ml hexane. Total lipid content was determined gravimetrically for each sample. The extracts were further purified by silica gel-alumina column chromatography. Field blanks, laboratory blanks, matrix spikes and duplicates were included for each set of samples collected.

All extracts from 2004 and 2005 samples were analyzed by a Thermo Finnigan DSQ quadrapole gas chromatograph–mass spectrometer (GCMS) and samples from 2008 and 2010 were analyzed by an Agilent 7890A GC with a 5975C quadrapole mass detector. Each GCMS was equipped with a 30 m DB-5 fused silica column for qualitative and quantitative identification of 37 individual PAH's, including parent compounds and homologs (**Table 2**). Oven temperature program was held at 50°C for two minutes and then programmed from 50°C to 280°C at 6°C min^{-1} and held at 280°C for 15 minutes with helium as the carrier gas. The mass spectrometer scanned from mass 40-500 in 0.5 sec at an ionization potential of 70 eV

A performance-based quality-assurance and quality-control program, which included the parallel analysis of procedural blanks and matrix spike, was implemented to ensure data of the highest quality. Procedural blanks consisting of diatomaceous earth did not contain target PAHs. Mean (± standard deviation) recoveries of sediments spiked with 14 parent PAH compounds was 87 ± 26%. Means ranged from 29% (napthalene) to 118% (benzo[a]anthracene). Recoveries for the two to three ring, low molecular weight PAHs and the four and five ring, high molecular weight PAHs had mean (± standard deviation) recoveries of 59 ± 21% and 102 ± 12%, respectively. Mean (± standard deviation) recoveries of o-terphenyl (OTP) added as a recovery surrogate prior to sample extraction was 83 ± 12%. All mass spectral data were compared to spectra produced by authentic standards and to previously published library spectra and by quantifying the base peak ion of each PAH against the base peak of the internal standard. The method of detection limit (MDL) was less than 1 ng/g for all samples and is defined as the mass of the analyte in the lowest detectable calibration solution multiplied by the extract volume and divided by the sample mass. Individual and standard mixtures of PAHs were purchased from AccuStandard (New Haven, CT, USA) or Sigma-Aldrich (St. Louis, MO, USA).

Bile Metabolites -Fish bile samples were collected in cryovials during dissection and snap frozen. Samples were shipped in a liquid nitrogen shipping dewar and stored in a -80^{0}C Freezer until analysis. The samples were then thawed and placed in autosampler vials with glass inserts (150 µL). Sub-samples were taken for bile weights with 5 µL samples averaged.

Standards were obtained from several sources. The parent compounds (naphthalene, phenanthrene, and benzo-*a*-pyrene) were purchased from Absolute Standards. The BAP metabolite standards (1-OH BAP and 3-OH BAP) were purchased from Midwest Research Institute. The naphthalene and phenanthrene metabolite standards (1-naphthol, 2-naphthol, 9-phenanthrol, and 2-phenylphenol) were purchased from Acros Organics (Fisher Scientific).

Every sample was run in duplicate, once for naphthalene-like and BAP-like metabolites and then a second time for phenanthrene-like metabolites. Two methanol blanks were run between each sample. Standards were run in triplicate before and after a sample set (10 samples). During each run, the FLD Wavelengths were set to analyze for each set of compounds based upon published excitation/emission wavelengths including: naphthalene-like metabolites (Ex/Em 293/335), phenanthrene-like metabolites (Ex/Em 260/380) and BAP-like metabolites (Ex/Em 380/430) as published previously (Krahn et al., 1986; da Silva et al., 2006).

An aliquot of 2.1 µL of bile was injected directly onto a Waters PAH C18 5µm – 3 x 250 mm column with a Waters Sentry Guard Column – Symmetry C18 5µm 3.9 x 20 mm and an Upchurch Scientific stainless steel Frit Filter 0.5 µm pre-filter. The samples with eluted with a linear gradient from 100% water (with 5 µL/L Acetic Acid) to 100% methanol at a flow of 0.510 mL/min. The total run time for each sample was 60 minutes. The column temperature was 50^{0}C.

<u>Results:</u>

2004

<u>Sediment</u>-Triplicate sediment samples were collected and analyzed from the following locations (**Figure 2**):

1) Ikpikpuk South
2) Ikpikpuk North
3) Joe Creek
4) Teshekpuk Lake area (two sites)
5) Trib 3
6) Itta Camp (only one sample collected at this location).

The average total PAH concentrations (in dry wt.) ranged from 3.55 to 6.62 ug/gdw (**Table 3, Figure 2**). The highest average values were found in the North and South Ikpikpuk River samples, although they were not significantly higher than the other sediment samples analyzed from the 2004 collections. **Appendix 1** shows the PAH distribution patterns for samples taken from these sediment collection locations. In general, the distribution profiles of the PAHs found in the Trib 3 and Itta Camp and two of the Joe Creek and one of the Teshekpuk lake area samples show a dominance of the phenanthrene/anthracenes, naphthalenes and fluoranthene/pyrenes followed by the other monitored series' of PAHs, with contributions from most of each of the homologs within each series. The profiles from the North and South Ikpikpuk and five of the Teshekpuk Lake area sediments were similar to each other but different from the samples above. Although there was a predominance of the same PAH series' (phenananthrene/anthracenes, naphthalenes and fluoranthene/pyrenes) there are few of the other monitored PAHs present. Additionally, the homolog distributions are weighted towards the less substituted PAHs rather than representing all alkyl substituted homologs as was generally found in the other sediment samples.

Fish tissue- Fish liver and muscle tissue were collected from multiple fish and analyzed individually for PAHs from the following locations (**Figures 3** and **4**):

1) Ikpikpuk South
2) Joe Station
3) Joe Creek
4) Teshekpuk Lake area
5) Trib 3

The results of these analyses indicate that broad whitefish muscle samples had very low levels of detectable PAHs present (**Table 3**, **Figure 3**). The total PAH concentrations ranged from undetected to 0.07 ug/gdw with the highest values found in Joe Creek fish samples. Liver, sub-sampled from the fish above, had average levels of PAHs ranging from undetected to 0.27 ug/gdw in the Trib 3 samples (**Table 3, Figure 4**). Generally, few homologs of the naphthalene series were found in either the liver or the muscle of the broad whitefish; however, some of the liver samples collected from Joe Creek and Trib 3 also had low, but measurable levels of some of the higher molecular weight PAHs (**Appendix 1**).

2005-2006

Sediment-Triplicate sediment samples were collected and analyzed from the following locations **(Figure 5)**:

1) Puvisuk
2) Uyagagvik Nigliq
3) CD2 location 1
4) CD2 location 2
5) Fish Creek
6) Woods Camp
7) TL003
8) TL004
9) TL005
10) Trib 3 (two sediment cores also taken from this location and sectioned into 25% depths for each core and analyzed individually).
11) Ikpikpuk DL Camp
12) TLSB2
13) Tesh Offshore Camp
14) DANLE

Sediment PAH concentrations for the Teshekpuk Lake area sites and the Ikpikpuk River stations were relatively low, ranging from 0.03 to 2.35 ug/gdw **Table 3**, **Figure 5**). Much higher concentrations were measured in the eastern locations near and on the Colville River. These values ranged from 3.04 to 12.0 ug/gdw, with the highest levels found at the Uyagagvik Nigliq and Puvisuk sampling sites with 8.49 and 12.0 ug/gdw, respectively.

The individual PAH distributions found in the Teshekpuk Lake area, Tesh offshore camp and Trib 3 sediments were dominated by the naphthalene series almost exclusively; however, two of the Tesh offshore samples had trace amounts of some of the higher ringed PAHs (**Appendix 1**). The profiles found at the Puvisuk and Uyagagvik Nigliq station locations were very different. These sediments had contributions of almost all homologs of each series of PAHs monitored, with a predominance of the phenanthrene/anthracenes, naphthalenes and fluoranthene/pyrenes followed closely by the fluorenes, dibenzothiophenes and the remaining targeted PAHs. This general profile was also found in the sediments from Woods camp and CD2; however there was little evidence of the fluorene and dibenzothiophene series of homologs in these samples, which were present in the Puvisuk and Uyagagvik Nigliq samples. Sediments from Fish Creek and Ikpikpuk DL camp contained PAHs with relatively high amounts of the naphthalenes compared with the other PAHs in these samples. The less substituted homologs were the dominant members of those series. The distributions found in the DANLE and Trib 3 sediment core samples shared similar PAH profiles, with no measurable amounts of the naphthalene series and small amounts of the phenanthrene/anthracenes and fluoranthene/pyrenes. The parent compounds and the less substituted members of the homologous series predominated. The profiles did not change with depth in the sediment core samples with contributions mainly from the parent compounds (**Appendix 1**).

Fish tissue and bile- Fish liver, muscle and bile were collected from multiple fish and analyzed individually for PAHs (for tissue) and PAH metabolites (for bile) from the following locations (**Figures 6 and 7**):

1) Puvisuk
2) Ruth Nukapigak
3) CD2 location 1
4) CD2 location 2
5) Woods camp
6) TL003
7) TLSB2
8) Ikpikpuk DL camp
9) TLSB2
10) 600/611 and DANLE

No PAHs were detected in fish liver, muscle, or bile.

2008-2010

Sediment-Sediment samples were collected and analyzed from the following locations (**Figure 9**):

1) Meade River FN Site
2) Meade River JN Site
3) Kuk River Site

The total PAH concentrations from these two locations were very low ranging from below detection limits to 0.80 ug/gdw (**Table 3**, **Figure 9**). The highest values were found in the Kuk River samples, although they were not significantly higher than those from the Meade River sites and all sediment samples had total PAH concentrations of <1.0 ug/gdw. The distributions for the Kuk River samples, while low in total concentration were significantly different than the distributions found in the Meade River samples suggesting a different input with evidence of fresh oil contributions of petroleum (**Appendix 2**).

Fish tissue- Fish liver and muscle tissue were collected from multiple fish and analyzed individually for PAHs from the following locations (**Figures 10** and **11**):

1) Meade River FN site
2) Meade River JN site
3) Moses Nayakik camp
4) Kuk River site
5) Wainwright Lagoon Inlet

The results of these analyses indicate that all muscle and liver from all the species of fish sampled had only trace amounts of naphthalene found in some of the samples (**Table 3**, **Figures 10 and 11**). The total PAH concentrations ranged from below detection limits to 0.48 ug/gdw with the highest values found in the Wainwright inlet fish samples which were measurable but very low. Due to the no detectable or extremely low levels found in the fish samples, no PAH distribution charts were created.

Conclusion:

Aromatic hydrocarbons from petrochemical combustion or from direct petroleum inputs can be characterized by the extent of alkylation. Those aromatics originating from direct petroleum inputs have a high degree of alkylation and those from combustion sources, a lesser degree. This lower degree of alkylation results from the cleaving of the substituted side chains during high temperature combustion (Wetzel and Van Vleet 2003). These homolog distributions can be used to discriminate petrogenic sources of PAHs from combustion sources in sediments.

There were several different PAH profiles found in this study, suggesting different or a combination of sources for petroleum inputs. In sediments from several locations [Trib 3, Itta Camp, Joe Creek (two locations), Teshekpuk Lake area, Meade River (2 locations) and Kuk River] had signatures suggesting petroleum or petrogenic inputs. Those samples from North and South Ikpikpuk River and the remaining Teshekpuk Lake area sediments had signatures that were higher in the two-ringed naphthalene series, indicating perhaps contributions from boat fuel, and some of the higher ringed PAH parent compounds and less substituted members of those series' suggesting pyrogenic or combustion sources.

This was the same type of profile found in the 2005 sediment samples taken from Trib 3 and Teshekpuk Lake area. The highest concentrations of PAHs were found in samples from Puvisuk and Uyagagvik Nigliq with the presence of all homologs in a typical petroleum signature indicative of petroleum sources. Levels of contamination were comparatively moderate at CD2 and Woods Camp and the signature there was slightly different, lacking measurable amounts of the fluorene and dibenzothiophenes, suggesting that perhaps there may have been a different source of oil input to those areas. The Fish Creek and DL Camp sediments were similar in PAH signature to those found in most of the 2004 Teshekpuk Lake area and Ikpikpuk River samples. The samples from DANLE and from the two cores taken from Trib 3 had characteristics of combustion or pyrogenic sources of PAH contamination. Samples from the Meade and Kuk River had very low levels of PAHs.

The Colville River, which drains a large part of the Brooks Range is the largest river which empties into the Beaufort Sea. The surrounding river area does not have well-developed soil and that soil transported via the Colville River carries with it fractions from coal and oil from natural seeps and oil-shale outcrops which occur in this watershed area (Steinhauer and Boehm 1992). This may help to explain in part the higher levels of PAH concentrations found in the Puvisuk, Uyagagvik Nigiq and CD2 locations.

Comparisons to previous sediment petroleum contamination studies can be made with the results from the current study to assess the degree of contamination that exists in this sensitive environment. This Arctic area is unique in its environmental characteristics, making it difficult to find suitable comparisons. However, the highest values found in this study are comparable to the lowest values found in more industrialized areas (Beg et al. 2002; Wetzel and Van Vleet 2003) and higher than PAH values found in a study of Beaufort Sea and Colville River mouth sediments (Steinhauer and Boehm 1992; Valette-Silver et al. 1999).

The assessment of sediments for evidence of contamination is a practical means of appraising the health of an environment. However, in general, this gives only a partial picture of the complexities involved in a dynamic ecosystem. It is very important to assess biological contaminants loads of a system as well. In this case, the biota examined were mainly broad whitefish and burbot. Overall, the body burdens of PAH contamination were very low and the main PAHs found in tissues (with measurable levels) were from the highly soluble naphthalenes, although some liver samples from Trib 3 also had some of the parent compounds of a few of the higher ringed PAHs. There were no PAHs detected in the 2005 fish samples nor were any PAH metabolites found in any of the fish bile samples.

In order to put this into a biological assessment framework to evaluate possible effects on the environment. There are two guideline values that are commonly used for this kind of biological effects evaluation (Long et al. 1995). They are effects range-low (ERL) and effects range-median (ERM) which delineate concentration ranges for a particular chemical. The concentrations below the ERL value represent a minimal-effects range; a range intended to estimate conditions in which effects would be rarely observed. Concentrations equal to and above the ERL, but below the ERM, represent a possible-effects range within which effects would occasionally occur. Finally, the concentrations equivalent to and above the ERM value represent a probable-effects range within which effects would frequently occur (Long et al. 1995).

The highest levels found in the consumable part of the fish, the muscle, were much less than the levels found by the USEPA to produce some effects on rats (USEPA 1998). Therefore it appears that there may be no risk associated with the consumption of the broad whitefish or burbot based upon the samples taken and analyzed during this study. In comparing the individual concentrations for each of the PAHs identified (**Appendix 2**) there are several incidences in which some of the targeted PAHs have exceeded the ERL (**Table 4**). This is the minimum range where effects would rarely be observed. In no instance did any of the individual PAHs meet or exceed the ERM or probable effects limit.

Food can be contaminated by environmental PAH that are present in air (by deposition), soil (by transfer) or water (by deposition and transfer), and during processing and cooking. The natural and anthropogenic sources of PAH in the environment are numerous. PAH compounds are emitted from a number of environmental sources, such as processing of coal, crude oil, petroleum, natural gas, production of aluminum, iron and steel, heating in power plants and homes (oil, gas, charcoal-fired stoves, wood stoves), burning of refuse, wood fires, and motor vehicle exhausts.

A 2002 report by the European Commission on Health and Consumer Protection on the risks to human health from PAHs in food states that except for naphthalene, there are only a limited number of studies available on the acute oral toxicity of PAHs. The LD_{50} values indicate that the acute oral toxicities of PAHs are moderate to low (European Commission Scientific Committee on Food 2002). The results of available oral short-term toxicity studies on PAHs are summarized in **Table 5**. A number of PAHs have been demonstrated to be genotoxic and carcinogenic. Therefore, the existence of a threshold cannot be assumed and the Committee could not establish a safe exposure limit. However, dietary assessment studies suggest that consumption of these

PAHs is much less than the no observable adverse effects level (NOAEL). It recommended that exposures to PAH should be as low as reasonably achievable.

There will likely be an expansion of drilling in the NPR-A region in the future. Because of this and because of the sensitivity of these lands due to their subsistence and environmental importance, continued monitoring studies are recommended for the future. Establishing comprehensive baselines in the near future will permit scientists to monitor changes in levels and sources of PAHs in sediments and in subsistence foods for Alaska Natives. Just as early detection of cancer is a key to successful treatment, early detection of contaminant problems and identification of likely sources can permit mitigation to protect a unique ecosystem, the wildlife that live there, and the Alaska Natives and others who depend on a healthy environment.

Products to date:

The results of the current study have already been made available in a number of fora, ranging from international and national conferences to a local presentation to residents of Barrow, Alaska. To date, the following presentations have dealt, in part or entirely, with the results of this project:

Reynolds, J.E., III and D.L. Wetzel. 2005. Bowhead whales, bearded seals, and Alaska native health. Barrow Arctic Science Consortium Outreach Series (supported by National Science Foundation), Inupiat Heritage Center, 3 May.

Reynolds, J.E., III, D.L. Wetzel, C. Hanns, P. Mercurio, and T.M. O'Hara. 2005. Analyses of polycyclic aromatic hydrocarbons in sediments, fish and marine mammals from the North Slope of Alaska. Proc. International Symposium on Oil and Gas Activities in the Arctic. Organized by Arctic Monitoring and Assessment Programme (AMAP), 13-15 September 2005, St. Petersburg, Russia: 594-598.

Wetzel, D.L., J.E. Reynolds, III, P. Mercurio and C. Hanns. 2006. Analysis of polycyclic aromatic hydrocarbons in sediments, fish and marine mammals from the North Slope of Alaska. National Forum on Tribal Environmental Science, Ocean Shores, WA, 24-28 September 2005.